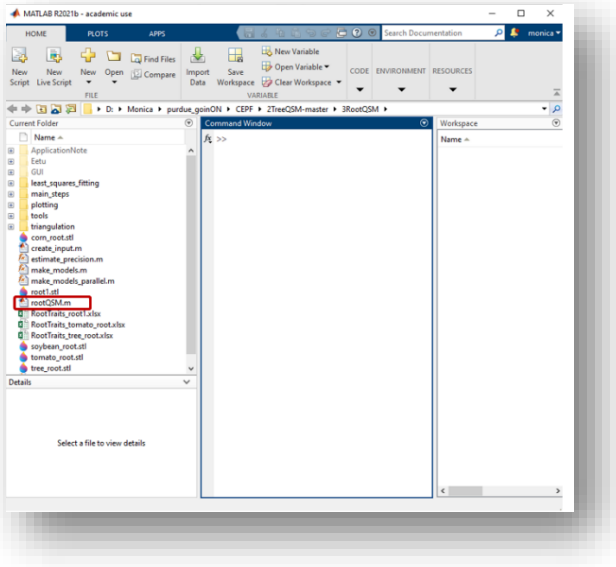
4DROOT SOFTWARE

INSTALL FROM MATLAB:

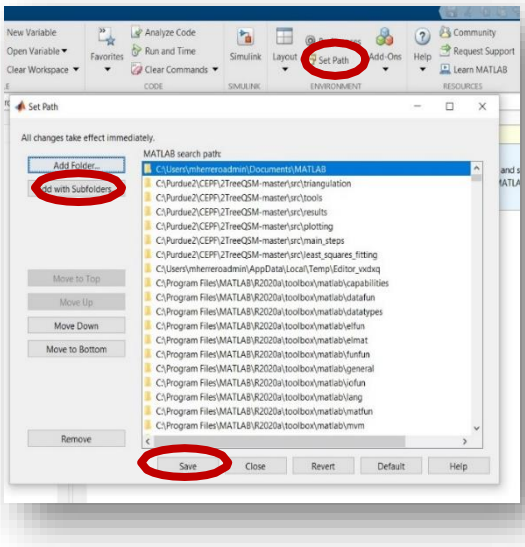
- COMPUTER VISION TOOLBOX
- PARTIAL DIFFERENTIAL EQUATION
- STATISTICS AND MACHINE LEARNING TOOLBOX

INSTRUCTIONS: CODE FOR MODELING THE ROOTS

1. Download 4DRoot
2. Start MATLAB 2017 or newer and set the main path to the root folder, where rootQSM.m is located (from 4DRoot).

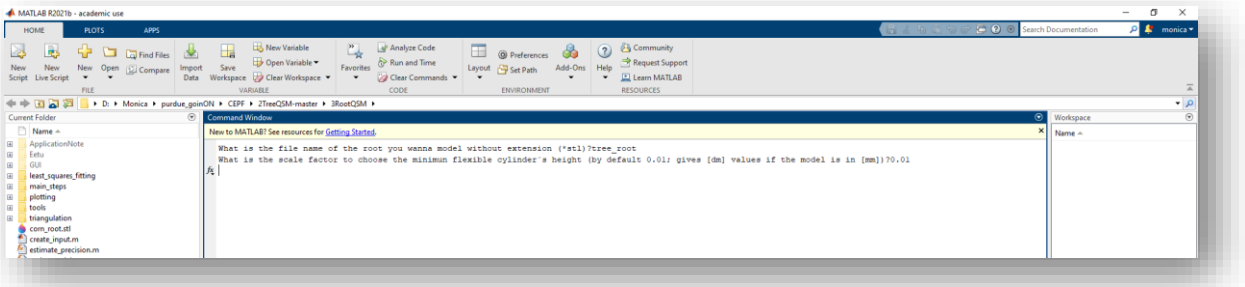


3. Use Set Path -> Add with Subfolders -> Open -> Save -> Close to add the subfolders, where all the code of the software is, to the paths of MATLAB.

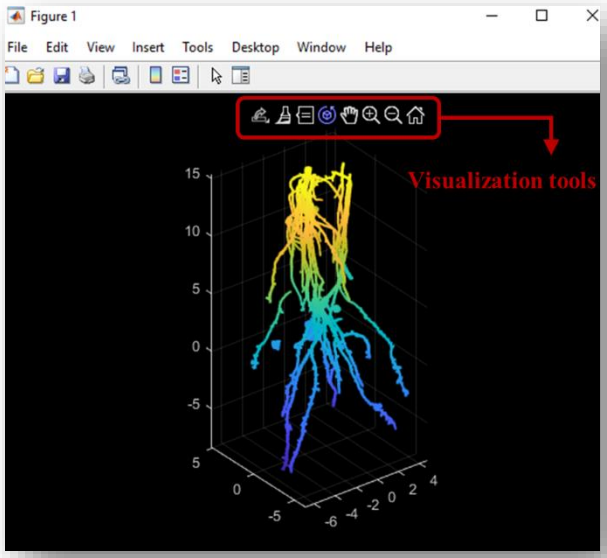


4. Run rootQSM.m:

4.1. Inputs: 3D scan of the root in *stl format, scale factor to reconstruct the cylindrical fitting and desire to view the 3Dscan.

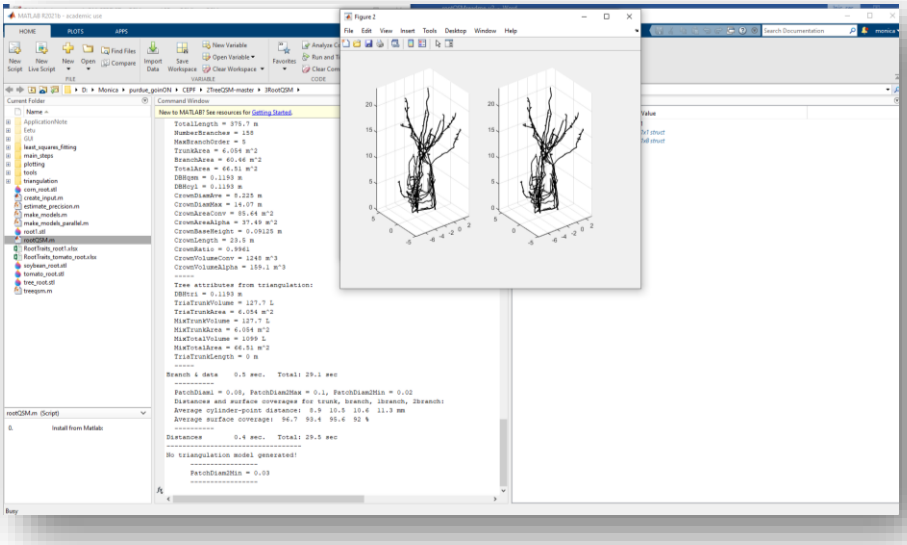


4.2. Visualization of the 3D scan as an option. Visualization tools are included.



After the visualization, the process is paused. To continue, press any key.

4.3. Numerical and graphic results of each approximation of the cylindrical model (upside down) when 3D Root is running.



4.4. Output: Phenotypic root traits and their distribution are extracted to an excel file with several sheets:

I. *Total Traits*: volume, height, length and area of the main and lateral roots, number and order of ramifications, crown diameter, convex-hull and alpha-shape crown area and volume, and 3D coordinates of the starting point.

II. *Ramification order traits*: volume, area, length and number as function of ramification order.

III. *Taproot taper*: taproot taper function, where the first row is the distance along the main root and the second row is its diameter.

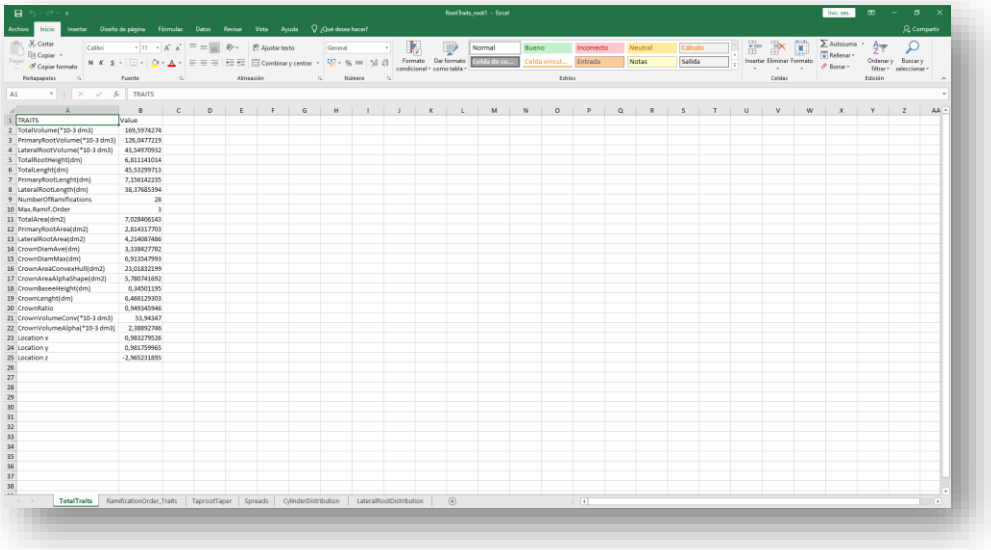
IV. *Spread*: horizontal spread of the root in 18 directions and in 10 height layers.

V. *Cylinder distribution*: geometric characteristics of the fitted main root-cylinders grouped in several classes:
   a. total volume, area, and length as a function of the diameter distribution of the cylinders (diameter classes by adding 0.1-mm per each class)
   b. total volume, area, and length as a function of the height distribution of the cylinders (height classes by adding 1-cm per each class)
   c. total volume, area, and length as a function of the zenith distribution of the cylinders (angle classes by adding 10º-angle per each class)
   d. total volume, area, and length as a function of the azimuth distribution of the cylinders (angle classes by adding 10º-angle per each class)

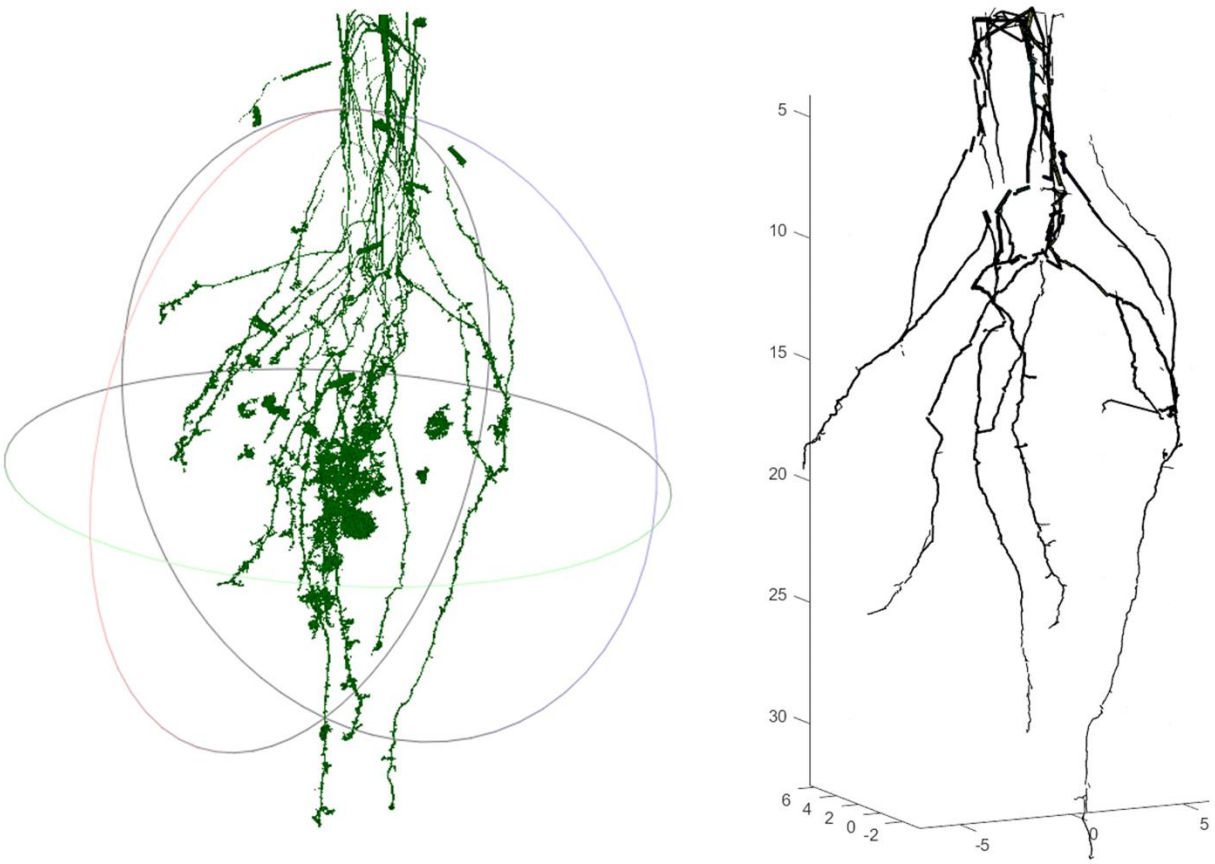
VI. *Lateral root distribution*: geometric characteristics of the fitted lateral root-cylinders grouped in several classes:
   a. lateral root volume, area, length, and number as function of the diameter distribution of the lateral root cylinders (diameter classes by adding 0.1-mm per each class)
   b. lateral root volume, area, length, and number as function of the height distribution of the lateral root cylinders (height classes by adding 1-cm per each class)
   c. lateral root volume, area, length, and number as function of the azimuth distribution of the lateral root cylinders (angle classes by adding 10º-angle per each class)
   d. lateral root volume, area, length, and number as function of the distribution of the lateral root cylinders (angle classes by adding 10º-angle per each class)

The units of the traits are:

- [L] as length and height: $[ud]$ from the scan / scale factor
- [L^2] as area: $[ud^2]$ from the scan / (scale factor^2)
- [L^3] as volume: $[ud^3]$ from the scan / (scale factor^3) $* 10^{-3}$



***Noise removal:** noise from the segmentation between soil and root can be removed by 4DRoot by choosing an appropriated *scale factor (left: 3D scan from a root, right: QSM from the root).*



CITE:

1. Herrero-Huerta, Monica, Pasi Raumonen, and Diego Gonzalez-Aguilera. "4DRoot: Root phenotyping software for temporal 3D scans by X-ray computed tomography." Frontiers in Plant Science 13 (2022).
2. Herrero-Huerta, M., Meline, V., Iyer-Pascuzzi, A. S., Souza, A. M., Tuinstra, M. R., & Yang, Y. (2021). 4D Structural root architecture modeling from digital twins by X-Ray Computed Tomography. Plant Methods, 17(1), 1-12.
3. Raumonen P, Kaasalainen M, Åkerblom M, Kaasalainen S, Kaartinen H, Vastaranta M, et al. Fast automatic precision tree models from terrestrial laser scanner data. Remote Sens. 2013;5(2):491–520.